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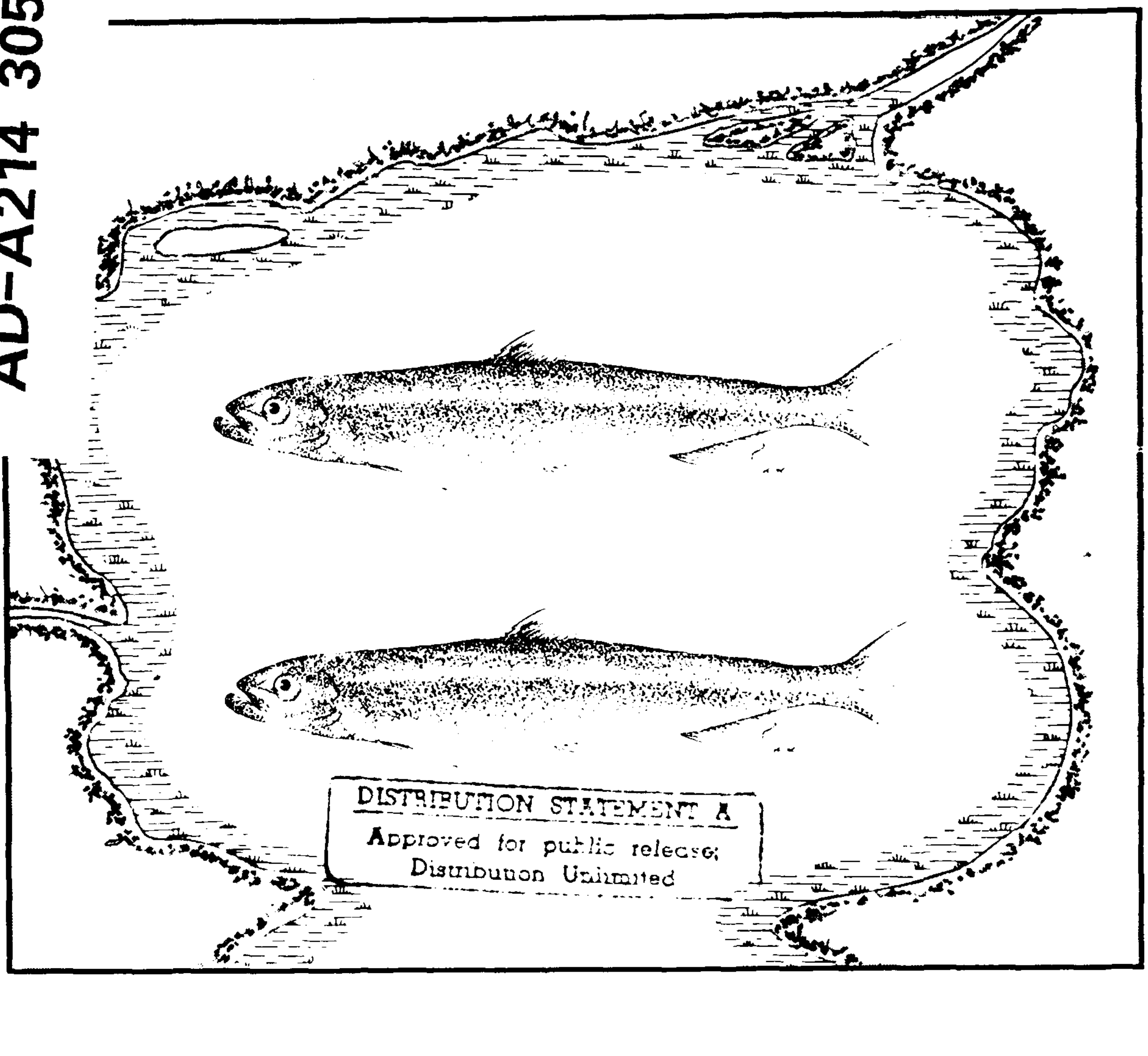

Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic)

RAINBOW SMELT

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Coastal Ecology Group
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Vicksburg, MS 39180

and

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Washington, DC 20240

PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

CONTENTS

ACKNOWLEDGMENTS

I am grateful for the reviews by S.A. Murawski, National Marine Fisheries Service, Woods Hole, Massachusetts, and Robert Lawton, Massachusetts Division of Marine Fisheries, Sandwich.

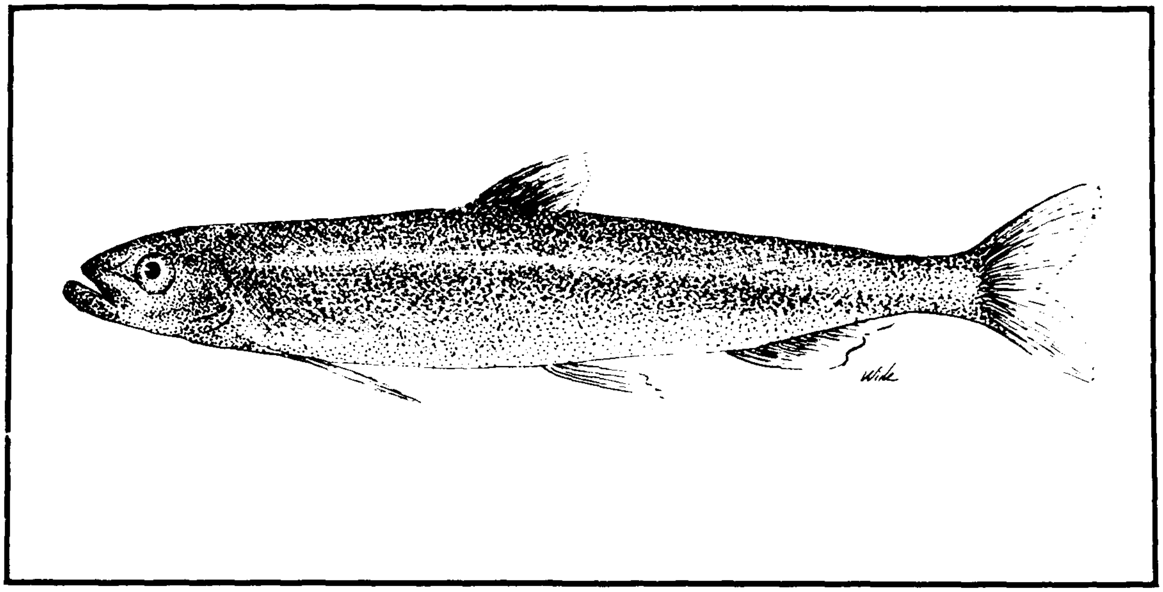

Figure 1. Rainbow smelt. (From Lee et al. 1980.)

RAINBOW SMELT

NOMENCLATURE/TAXONOMY/RANGE

Scientific name........<u>Osmerus</u> <u>mordax</u> (Mitchill) 1815
Preferred common name....Rainbow smelt (Figure 1)
Other common names..............smelt, American smelt, leefish, freshwater smelt, frost fish (Scott and Crossman 1973)
Class.....................Osteichthyes
Order....................Salmoniformes
Family......................Osmeridae

Geographic range:

Rainbow smelt are distributed along the east coast of North America from eastern Labrador and the Gulf of St. Lawrence south to the Delaware River (Figure 2). Smelt occur naturally in lakes and ponds in New Hampshire, Maine, New Brunswick, Nova Scotia, and Newfoundland (Bigelow and Schroeder 1953). The range of smelt was greatly extended when they were introduced into the Great Lakes in the early 1900's (Van Oosten 1937; Dymond 1944). The species is now abundant in all of the Great Lakes (Scott and Crossman 1973). Smelt were first reported in the Mississippi drainage by Burr and Maydew (1980).

MORPHOLOGY/IDENTIFICATION AIDS

The following description of the rainbow smelt is compiled from Bigelow and Schroeder (1963) and Scott and Crossman (1973).

The smelt's body is slender and elongated with a long, pointed head, large mouth, protruding lower jaw. maxillary extending to middle of eye, deeply forked tail, and a small but evident adipose fin. Cycloid scales number 62-72 in lateral series; the peritoneum is silver with dark speckles. Nuptial tubercles develop on the head, body, and fins of males. The color is transparent olive to pale green on the back; the sides are similar, each with a broad longitudinal silvery band. When smelt are freshly caught, sides may have a

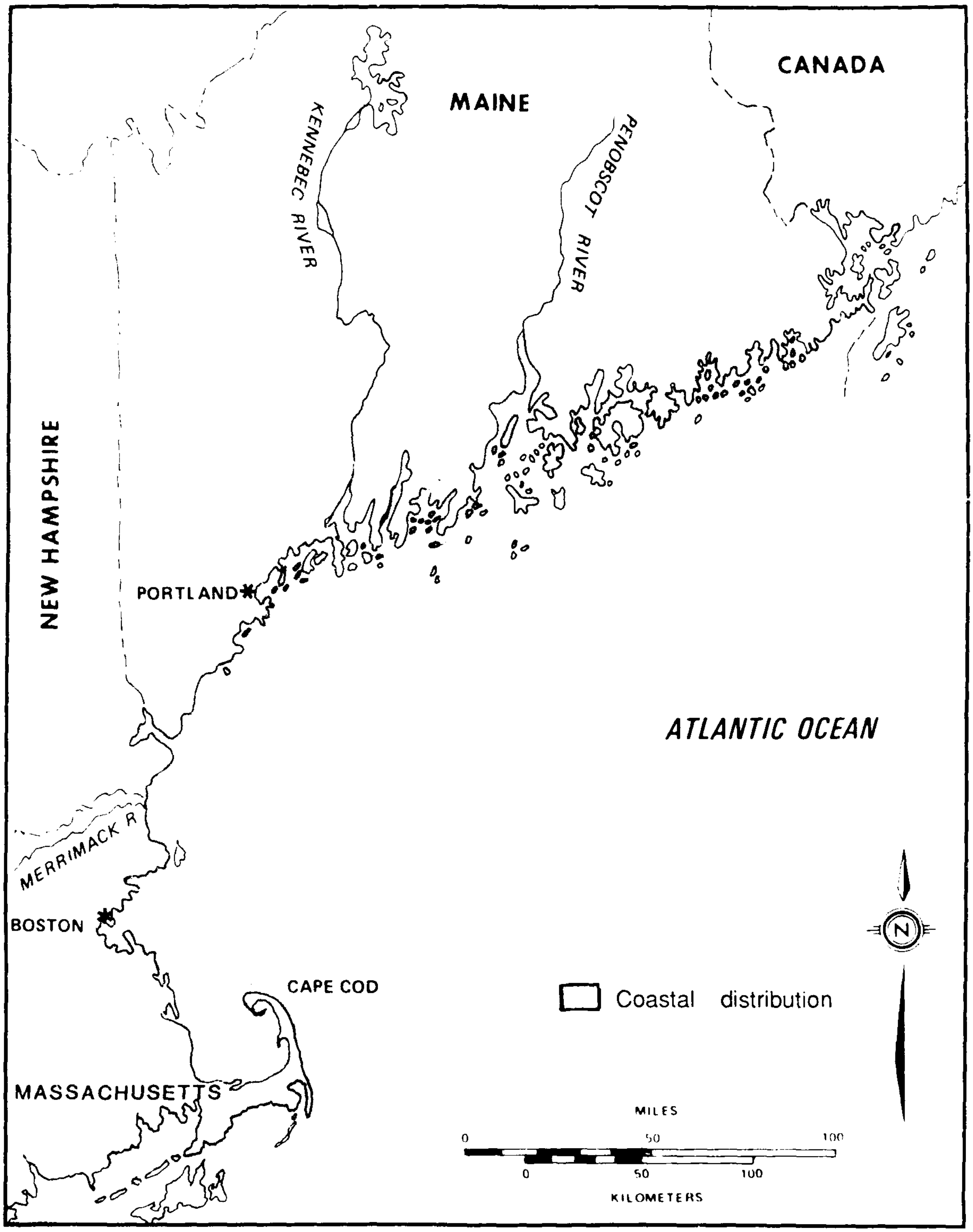

Figure 2. Distribution of rainbow smelt in the North Altantic Region.

purple, blue, and pink iridescent reflection; the belly is silver.

The taxonomic relationships among members of the genus *Osmerus* have been the subject of persistent controversy. Although there have been numerous efforts to clarify the taxonomy, including a systematic revision by McAllister (1963), the relationships remain obscure. A review of the controversy and present status is given by Scott and Crossman (1973).

REASONS FOR INCLUSION IN SERIES

The rainbow smelt is an abundant forage fish, preyed upon by many commercially and recreationally valuable coastal marine species, such as striped bass, *Morone saxatilis*, and bluefish, *Pomatomus saltatrix* (Smith and Wells 1977). In the Great Lakes it is the prey of several species of salmon and trout (Scott and Crossman 1973; Stewart et al. 1981). In addition, the species supports an important coastal and estuarine sportfishery throughout most of its range, particularly in the Great Lakes, New England, and eastern Canada.

LIFE HISTORY

Spawning and Migration

Rainbow smelt are anadromous, spawning in freshwater and growing and maturing in estuaries and coastal waters. Naturally occurring or introduced freshwater populations have similar migrations into streams for spawning, although successful shore spawning has been documented (Rupp 1965).

In coastal streams, most smelt spawn above the head of the tide. Spawners usually begin to move into spawning areas before the ice breakup (McKenzie 1964). Spawning usually peaks with bimonthly spring tides (Clayton 1976). Depending on location, peak spawning occurs in late March through late May (Clayton 1976). Along the east coast, smelt spawn at water temperatures of 4.0 to 9.0 °C (Clayton 1976). An exception to this is in the Miramichi Estuary, New Brunswick, where McKenzie (1964) reported early and late runs into the spawning area. Early spawning runs began when water temperature reached 10 °C and later spawning runs lasted until water temperature reached 15 °C. In some freshwater populations, spawning occurs at higher temperatures; Jilek et al. (1979) reported reproduction in Lake Michigan at 10 and 18 °C.

Typically, the substrate in the spawning area of coastal streams is gravel, with water depths at low tide of 0.1 to 1.3 m (Murawski et al. 1980). According to Clayton (1976), spawning site selection is influenced largely by water velocity rather than depth or substrate. Sutter (1980) found a significant positive relationship between survival to the early-eyed egg stage and increasing water velocity (up to 60-80 cm/s). Hulbert (1974) found the greatest number of eggs deposited in areas of highest velocity.

The degree of genetic homogeneity within an estuary with multiple spawning streams appears to be related to distance between streams. A mark and recapture study by Murawski et al. (1980) showed that individual fish sometimes spawn in several streams in an estuary during the spawning period. Rupp (1968) found similar "wandering" of spawning fish between streams for a freshwater population in Maine. Frechet et al. (1983) used variations in meristics, growth, and fecundity to assess the degree of spatial integrity of smelt groups in rivers. They found that homing to spawning rivers is rare when distances between rivers within a geographic area such as an estuary are small. In contrast, studies in the Miramichi River found only occasional movement of spawning fish between streams (McKenzie 1964). Distance between streams used for spawning could be an important factor in assessing the effect of short-term environmental disturbances on smelt populations.

In coastal waters, smelt spawn at night and most return to the estuary during the day, although some males may remain in the spawning area (McKenzie 1964; Clayton 1976). Usually several males attend one female during spawning (Langlois 1935; Clayton 1976). Smelt in the spawning runs are predominantly males, but sex ratios vary widely over the duration of the spawning run (Kendall 1927; Langlois 1935; Warfel et al. 1943; McKenzie 1964). The preponderance of males can be attributed to the longer spawning period for males (Murawski et al. 1980). Rupp (1968) reported that individual males may spawn on as many as 8 nights consecutively, whereas females may spawn only 3 to 4 nights.

The age of new recruits in spawning runs shows clinal variation along the east coast, increasing with latitude. In the Parker River, Massachusetts, age I fish made up 26% of the spawning run (Murawski 1976), whereas age I spawners were scarce or absent in a more northerly population in Great Bay, New Hampshire (Warfel et al. 1943). In the Miramichi River, all spawners were ages II (66%), III (30%), or IV (4%) (McKenzie 1964). An introduced population in Lake Superior was not fully recruited into the spawning population until age III (Bailey 1964). The attainment of maturity in smelt appears related to size; thus, fish in the more southerly populations with faster growth rates mature at an earlier age.

Eggs

Clayton (1976) reported fecundities of 7,000 to 44,000 eggs for fish from the Parker River, Massachusetts. For the Miramichi estuary in New Brunswick, McKenzie (1964) reported fecundities of 8,500 eggs for a fish of 12.7 cm TL and 69,600 eggs for a fish of 20.9 cm TL. Fertilized eggs are demersal, adhesive, and range in size from 1.0 to 1.2 mm (Crestin 1973; Cooper 1978).

Water velocity, substrate type, and egg density appear to be important factors in egg survival. Sutter (1980) found a significant positive relationship between survival to the early-eyed stage and rate of flow from 60 to 80 cm/s. Typically, eggs are deposited over gravel; mean survival rates reported have been 0.8%-1.8% (McKenzie 1964), 1.06% (Rupp 1965), 0.55% (Rothschild 1961), and 1.01% (Sutter 1980). In contrast, Sutter (1980) observed a survival rate of 10% when eggs were deposited on aquatic vegetation.

Hatching success has been shown to be related to egg density; McKenzie (1964) reported 3.6% hatching success at a density of 487 eggs/ft^2. In Maine, maximum production of yolk-sac larvae was at 11,745 eggs/ft^2 (Rothschild 1961). Egg crowding results from spawning fish encountering obstructions in their upstream migration.

Incubation time for eggs was 29 days at 6 to 7 °C; 25 days at 7 to 8 °C; 19 days at 9 to 10 °C; 11 days at 12.0 °C, and 8 days at 16.5 °C (McKenzie 1964; Cooper 1978).

Major predators on smelt eggs are the common mummichog, (*Fundulus heteroclitus*) and fourspine stickleback (*Apeltes quadracus*) (Sutter 1980).

Yolk-sac Larvae

The larvae at the time of hatching are 5 to 6 mm long (McKenzie 1964; Clayton 1976; Cooper 1978). Yolk-sac larvae have been reported to be negatively phototactic (Rupp 1965). The yolk sac is absorbed when the larvae are about 7 mm long. After hatching, the larvae drift downstream, where they are concentrated near the surface (McKenzie 1964; Crestin 1973). As the larvae grow, they tend to congregate on the bottom in deeper areas (Clayton 1976). Using plankton nets, McKenzie (1964) took 90% of the larvae collected within 5 ft of the bottom. At night they moved near the surface, apparently to feed (McKenzie 1964). It has been postulated that larvae are maintained in an estuary by the two-way transport system (Rogers 1939).

Juvenile/Adult

As the smelt grow, they move into waters of increased salinity in the lower estuary or into nearshore coastal waters (Crestin 1973). Smelt begin to school when they are about 19 mm long (Belyanina 1969), moving into shallow water at night and returning to deeper channels during the day. Young fish have also been observed in eelgrass (*Zostera marina*) beds (Crestin 1973). In the fall, as water temperatures drop, juveniles move into the upper estuary, concentrating in channels, where they mix with adult smelt (McKenzie 1964; Clayton 1976).

After spawning, adults return to saltwater to spend the summer in the estuary or in a narrow zone along the coast. Smelt have never been reported more than 2 km from shore or in water depths greater than 6 m (Bigelow and Schroeder 1953). In the fall, adults return to the estuary where they overwinter before beginning their spring spawning run.

GROWTH CHARACTERISTICS

Growth Rate

Growth in length is greatest in the first year and decreases thereafter. After females reach maturity (at age I, II, or III, depending on location), they grow faster than males (Warfel et al. 1943; Bailey 1964; Murawski and Cole 1978). Smelt in marine populations usually grow faster than those in freshwater populations, and smelt in northern marine populations grow slower than those in more southerly populations. In the Parker River in Massachusetts, the mean total lengths (sexes combined) for smelt ages I through V were 141, 192, 213, 240, 245 mm, respectively (Murawski 1976). In Great Bay, New Hampshire, the mean total length for age I was 86 mm; age II, 145 mm; age III, 171 mm; and age IV, 245 mm (Warfel et al. 1943). In the Miramichi River, New Brunswick, mean total lengths for ages II-V were 139, 165, 187, and 206 mm, respectively.

For smelt in the Parker River, Massachusetts, Murawski and Cole (1978) gave the von Bertalanffy growth equation for the first year as:

$$TL = 102.14\ (1-e^{-2.7769(t-0.0673)})$$

where TL = total length in mm and t = years.

Length-weight Relationships

Table 1 contains published equations for length-weight relationships for adults and juveniles.

THE FISHERY

Sport and Commercial

Smelt support a hook-and-line sportfishery in coastal waters and a dipnet sportfishery during the spawning run (Bigelow and Schroeder 1953). A small commercial fishery in eastern Canada and the Gulf of Maine uses trapnets (McKenzie 1964). In 1976, the total smelt harvest in the coastal waters of New England was 105,000 lb (U.S. Department of Commerce 1980). In 1976, commercial landings from U.S. waters of the Great Lakes totaled 23,580,000 lb (U.S. Department of Commerce 1980).

Table 1. Equations for length-weight relationships for adult and juvenile rainbow smelt.

Age group	Location	Equation	Source
Adults			
	Lake Superior	Log W = -2.57962+2.95233 log L	Bailey 1964
	Gull Lake, MI	Log W = -5.0952+2.9539 log L	Burbidge 1969
	Parker River, MA	Log W = -6.0315+3.3592 log L	Murawski and Cole 1978
Juveniles			
	Weweantic River, MA	Log W = -2.73+3.51 log L	Crestin 1973

Population Dynamics

Age II smelt are fully recruited into the fishery along the entire range of the species in the North Atlantic (McKenzie 1964; Murawski and Cole 1978). From Massachusetts southward, age I smelt are recruited into the spawning runs but none are taken by the fishery. Murawski and Cole (1978) attributed this to either habitat segregation of age groups or gear selectivity.

In the Parker River, Massachusetts, the mortality of adults is about 72% and is apparently greater among males than females (Murawski and Cole 1978). This is probably because males spend more time on the spawning ground.

Historically, declines in smelt abundance in Massachusetts have been linked to industrial pollution, blockage of spawning migration by dams, and possibly the loss of estuarine habitats such as eelgrass beds crucial to specific life stages (Bigelow and Schroeder 1953; Crestin 1973).

ECOLOGICAL ROLE

Food Habits and Feeding Behavior

Larval and juvenile smelt in coastal waters feed on copepods and other planktonic crustaceans. Larger juveniles and adults feed on euphausiids, amphipods, polychaetes, and fish (Flagg 1972). Adults were reported to feed on small mummichogs, cunner, anchovies, sticklebacks, Atlantic silversides, and alewives (Bigelow and Schroeder 1953).

In the Great Lakes, smelt larvae fed mainly on dipteran larvae, crustaceans, and fish (Gordon 1961; Burbidge 1969). In Lake Michigan, adults and juvenile smelt fed largely on *Mysis* in the winter and young-of-the-year and yearling alewives in spring and summer; they began feeding actively at dusk and ceased by nightfall (Foltz and Norden 1977).

Predators

Smelt are the food of many predators. Larvae and juveniles are probably eaten by most estuarine piscivores. Adult smelt are preyed upon by bluefish, striped bass, harbor seals, and other large predators (Clayton et al. 1978).

Since they were introduced into the Great Lakes, smelt have become a major forage fish (Argyle 1982) and the primary food of the lake trout (*Salvelinus namaycush*) (Stewart et al. 1981).

ENVIRONMENTAL REQUIREMENTS

Temperature

In tests to assess the effects of acute thermal shock, rainbow smelt showed the lowest tolerance when tested in seawater (Barker et al. 1981). A sharp increase in water temperature and increased salinity might act synergistically to induce stress and mortality in larval smelt.

Most of the local migrations of smelt in estuaries are searches for optimum water temperature (Bigelow and Schroeder 1953). Sudden decreases in water temperature can cause temporary cessation of spawning, and prolonged low temperatures can result in a protracted spawning period (Murawski et al. 1980).

Salinity

The exposure of smelt eggs to salt or brackish water can adversely affect embryonic development and lead to high egg mortality. In incubation tests, salinities of 12 to 14 ppt were fatal to eggs. Pathological changes were also observed in the eggs of a closely related species, *Osmerus eperlanus*, at salinities greater than 13 ppt by Unanian and Soin (1963). They found that in addition to causing increased egg mortality, high salinity (>26 ppt) can prevent fertilization.

Any activity that increases salinity in spawning areas could have severely deleterious effects on reproductive success.

Contaminants

The effects of chlorination on smelt were studied by Seegert and Brooks (1978). They reported that at 10 °C the 30 min LC_{50} was 1.27 mg of chlorine per liter. Mortality was slight at 0.72 mg/l and nearly complete at 2.0 mg/l. Effects of other contaminants on smelt have not been reported.

Disease and Parasites

Several diseases are common among smelt populations. Piscine erythrocytic necrosis (PEN), a viral disease, infects smelt populations from the Canadian provinces to Massachusetts, but occurs at low levels in individual fish (Sherburne and Bean 1979). Supporting this, Jimenez et al. (1982) in a study on the occurrence of PEN in smelt from Massachusetts coastal rivers found a high incidence of infection (61% to 97%) within populations, though less than 1% of the erythrocytes of individual fish were infected. Deleterious effects of PEN on smelt have not been described, although Evelyn and Traxler (1978) found severe anemia in two species of salmon infected with the disease. Jimenez et al. (1982) speculated that PEN acting synergistically with other factors may be debilitating and ultimately cause mortality.

The microsporidian *Glugea hertwigi* has been found in marine and freshwater populations, and is another cause of debilitation and mortality in smelt (Haley 1953; Nepszy and Dechtiar 1972; Chen and Power 1972; Jimenez et al. 1982). Jimenez et al. (1982) reported a mean infection rate of 13.4% (range 0-18%) in Massachusetts coastal rivers; Haley (1953), working in Great Bay, New Hampshire, reported a 23.3% infection rate. The debilitating effects of this parasite have been documented in several studies. Jimenez et al. (1982) found that weight and total length were significantly different between infected and noninfected fish. Chen and Power (1972) examined smelt populations in Lake Ontario and Lake Erie and found the incidence of microsporidian infection was 5.2% and 62.7%, respectively. Because the infection causes ovarian tissue to be replaced with parasitic cysts, the Lake Erie population suffered a decrease in fecundity.

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16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, life history, and environmental requirements of coastal fishes and aquatic invertebrates. They are designed to assist with environmental impact assessments. The rainbow smelt is an abundant forage fish for commercially and recreationally valuable fishes such as striped bass and bluefish on the east coast and several species of salmon and trout in the Great Lakes. The rainbow smelt also supports an important sportfishery throughout most of its range. In 1976, the total smelt harvest in the coastal waters of New England was 105,000 lb. Coastal rainbow smelt are anadromous, spawning in freshwater and maturing in saline water. Spawning peaks in spring. Salinities above 12 ppt were fatal to eggs. Reported fecundities are 7,000 to 44,000 eggs per female. Smelt are always found in shallow water (<6 m deep) and within 2 km of the shore. Larval and juvenile smelt along the coast feed on planktonic crustaceans. Larger juveniles and adults feed on euphausiids, amphipods, polychaetes, and fish. Smelt move locally to search for optimum water temperatures.

17. Document Analysis a. Descriptors

Estuaries	Fishes	Salinity
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Feeding habits	Temperature	

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Osmerus mordax,	Ecological role

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